

A POLARIZER FOR THE VACUUM ULTRAVIOLET

*Johnson  
Gehrke  
de Wasse*

Abstract

The construction and optical properties of a  $\text{MgF}_2$  double Rochon prism useful as a polarization analyzer for the vacuum ultraviolet region to 1300A in a satellite-born single beam astronomical photopolarimeter is described. Measures of  $\text{MgF}_2$  transmission and birefringence from 1150A to 2900A are presented.

Introduction

An ultraviolet photopolarimeter proposed for an astronomical satellite experiment calls for a polarizer which transmits and efficiently polarizes in the region 3000 to 1300A. In order to employ a stationary detector with a rotating analyzer, a device is needed which does not deviate the polarized beam. In addition, an acceptance angle sufficient to work with  $f/8.5$  to  $f/13$  collecting optics is required. This paper describes a double Rochon prism of optically contacted  $\text{MgF}_2$  elements developed for that application.

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Prism Design

A basic Rochon prism, while it does deviate the light of one polarization and passes the other undeviated, tends to be very long compared to its aperture when designed for large beam separation and large acceptance angles.  $\text{MgF}_2$  is the most birefringent crystal known to transmit from the visual to the 1300A region. The modest birefringence of  $\text{MgF}_2$  further increases the length of a Rochon prism by requiring a very small prism angle. In order to reduce absorption losses, the prism shown in Figure 1 was developed. This three-element prism acts like two stacked Rochons and is just half the length of the equivalent two-element Rochon.

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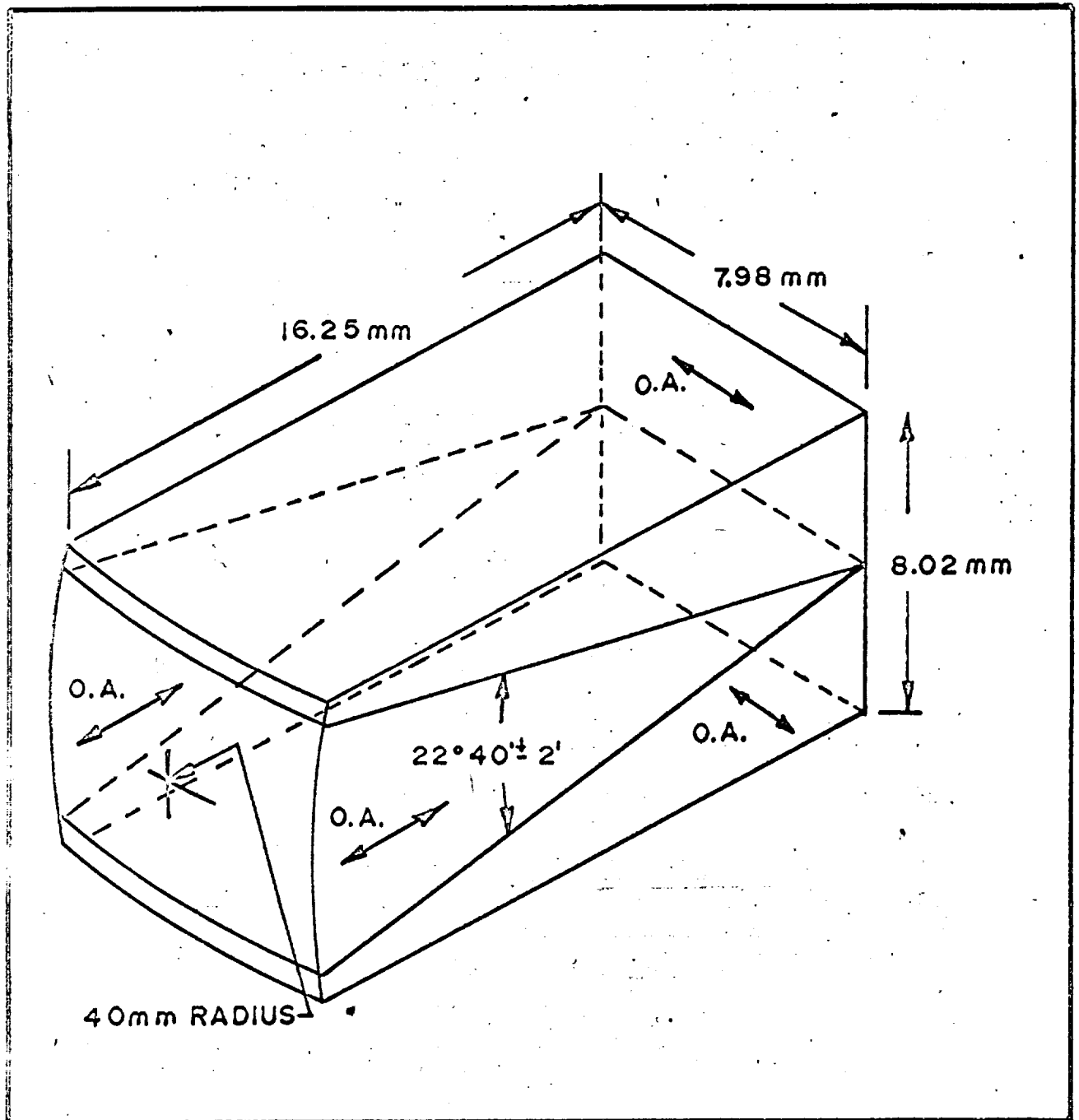


Figure 1, Double Rochon Prism

The prism is to be placed between the focal plane diaphragm of a telescope and a photoelectric detector. For this reason the entrance face of the prism is convex to function as a field lens. Behind the prism the two extraordinary beams are obstructed by a mask and only the undeviated ordinary beam reaches the detector.

### Prism Fabrication

As no known cements transmit in the 1300A region some initial experiments were conducted with optically contacted  $\text{MgF}_2$  before attempting to make a double Rochon prism. Two 25mm diam.  $\text{MgF}_2$  Lyot depolarizers were successfully contacted without cement. A gain in transmission of 4% (at normal incidence) was measured from 6000A to 2200A for contacted vs airspaced elements. One of the depolarizers was vibrated to 40g's from 20 to 3500 cps without deterioration in optical contact. A  $\text{MgF}_2$  single Rochon prism 55x10x10mm was built, but could not be successfully contacted without the use of a pressure clamp. Based on the design of Figure 1, two MgF prisms were fabricated. The first prism, a double Sénarmont<sup>1</sup> was maintained in optical contact by a clamp mount. The second, a double Rochon<sup>2</sup> was fabricated oversized with interface surfaces flat to 1/20 wave or better. The elements were placed in unclamped optical contact. The prism was then worked to size and the end faces generated.

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1. The double Sénarmont made by custom optics of Tucson, Arizona is identical to the double Rochon with the exception that the axial orientation of the two side pieces in the Sénarmont are vertical in Figure 1.
  2. Fabricated by Valprey Corporation, Holliston, Mass. (to LPL specification for Precision Optics of Costa Mesa, Calif.)

### Transmission

The transmission of the two completed prisms were measured with a McPherson 240 vacuum ultraviolet spectrometer<sup>3</sup> with a Hinteregger source. An EMI 9514S photomultiplier with a sodium salicylate window was used from 2900 to 1500A and an EMR 541H solar blind CuI cathode detector from 2000 to 1100A. Fluorescence in the chamber interfered with measurements at 1450A and shorter when the sodium salicylate detector was used. No fluorescence was detected with the solar blind detector even when the prism was exposed to 1000A lines well beyond it's transmission cutoff.

The prism transmission data of Figure 2 is based on measures at 85 wavelengths at approximately 20A intervals from 2900A to 1100A. In these measures all three exit beams from the prisms are collected by the detectors. The transmission of the mechanically clamped prism is significantly lower than the other.

The transmission of four samples of  $MgF_2$  cut from the same boule in the range 1162A to 2600A was measured. These data are shown in Figure 3 and the E and O absorption coefficients derived from them are given in Table 1.

### Birefringence

The usefulness of the prism as a polarization analyzer depends upon adequate beam separation. This quantity was measured by direct photography inside the McPherson 240, using Eastman 103a0 and Eastman SC-5 films (the latter from 1450 to 1200A), placed a measured distance behind the prism. A sequence

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3. The authors are greatly indebted to Dr. Hunten, Kitt Peak National Observatory and KPNO for the use of the McPherson Model 240.

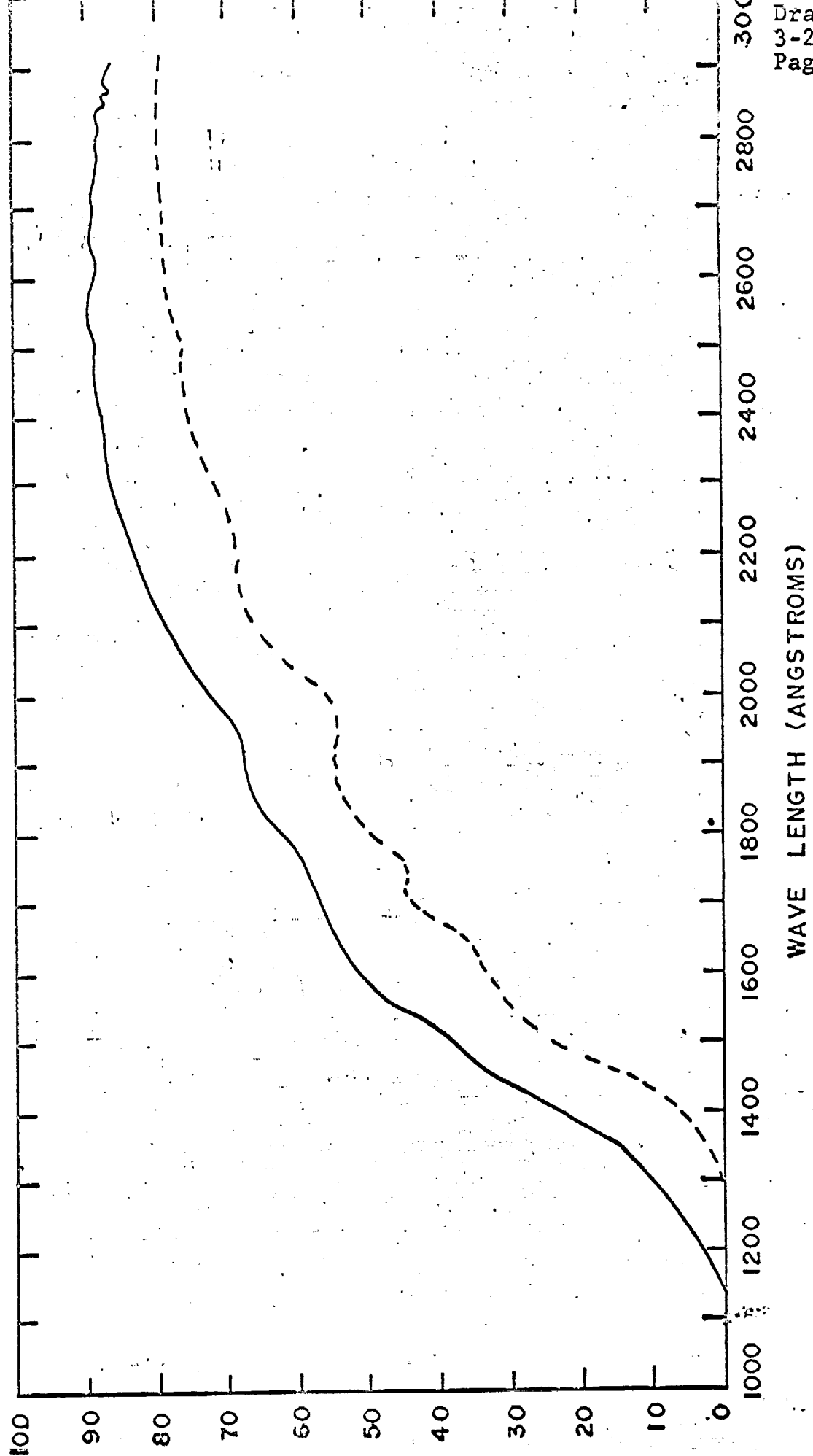


Figure 2, Prism Transmission

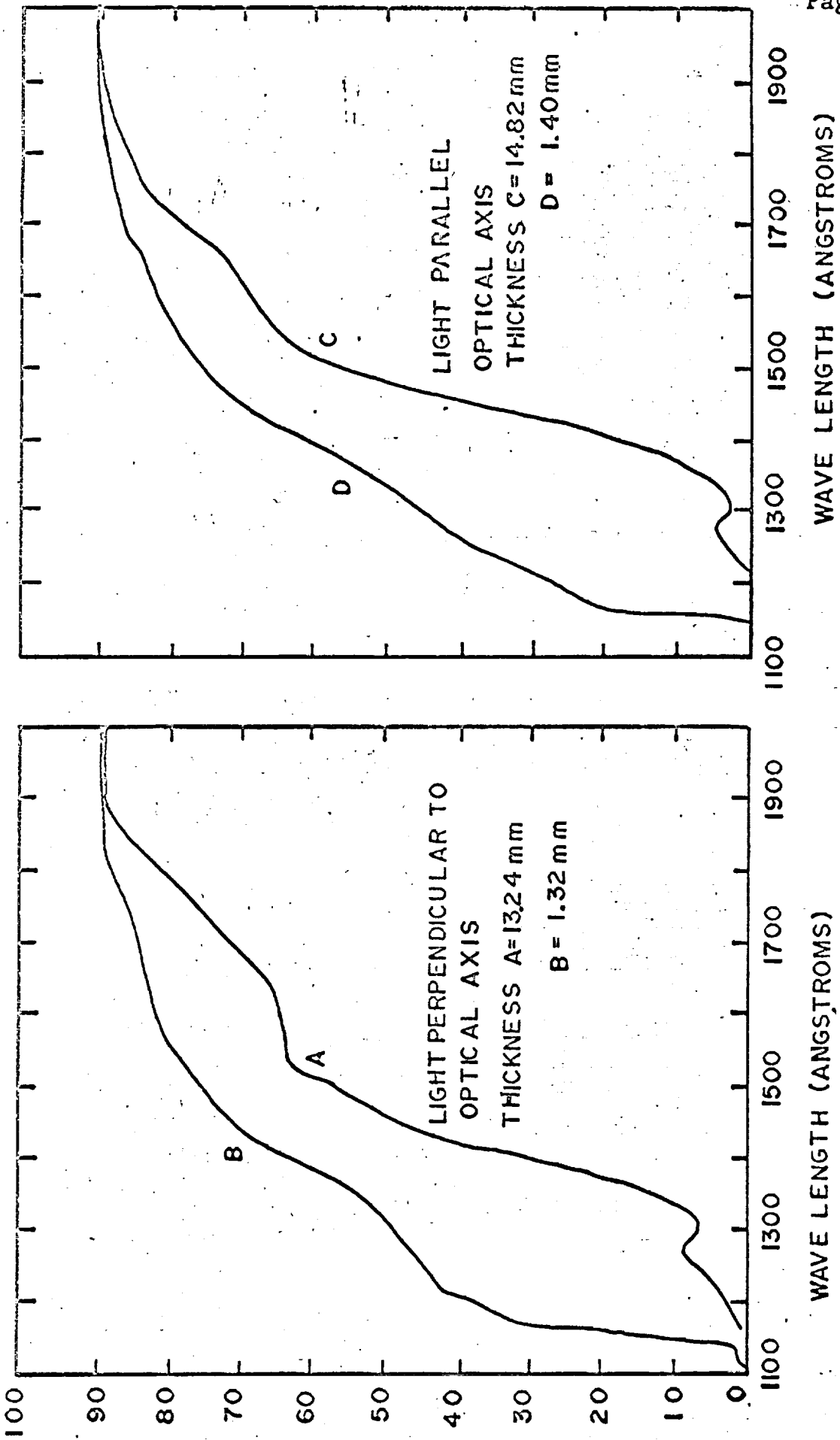


Figure 3, MgF<sub>2</sub> Transmission

TABLE 1  
THE ABSORPTION COEFFICIENTS OF  $\text{MgF}_2$   
IN THE ULTRAVIOLET

$\lambda$ (Å)	EXTRA- ORDINARY RAY $\text{CM}^{-1}$	ORDINARY RAY $\text{CM}^{-1}$
1212	.75	3.43
1262	1.03	1.77
1314	1.24	2.24
1332	1.06	1.98
1400	.35	0.93
1439	.28	0.50
1500	.22	0.22
1550	.21	0.15
1600	.25	0.15
1650	.24	0.14
1675	.20	0.10
1750	.17	0.05
1800	.12	0.04
1850	.04	0.02
1900	.01	0.01
1925	.01	0.01
1950	.02	0.01
1975	.01	0.01
2000	.01	0.01
2050	.00	0.01
2150	.00	0.01
2200	.00	0.01
2250	.00	0.00

of 4 of these records is reproduced in Figure 4, showing the rapid decrease in birefringence with decreasing wavelength.

Independent measures of indices of refraction of  $\text{MgF}_2$  from 2900 to 1780A kindly supplied by T. Teska<sup>4</sup> are given in Table 2. We have used these indices and a computer ray-trace to derive a differential correction to correct for distortion in the E beams, in reducing the measured beam separations from the photographic records to an angular divergence normalized to paraxial rays. These reduced measures appear in Figure 5, together with the divergence predicted for the prism with Teska's indices.

### Fluorescence

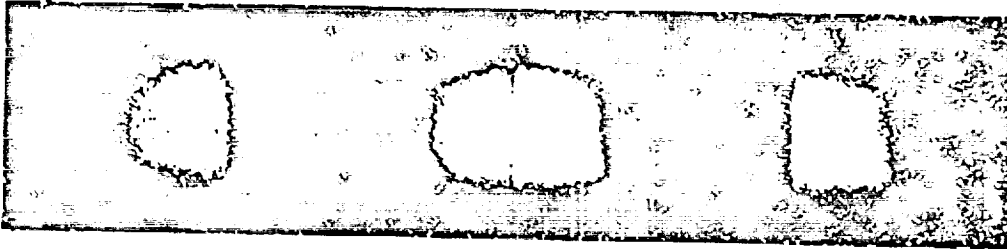
During the photographic measures as well as the transmission measures strong fluorescence was encountered. However, when baffles were added to prevent light from any source other than the prism from reaching the film the background fog was reduced. It is only on exposures at 1436A and shorter wavelengths, that background fog due to scattered or fluorescent light from, (or passing thru) the prism itself was detected.

### Conclusions

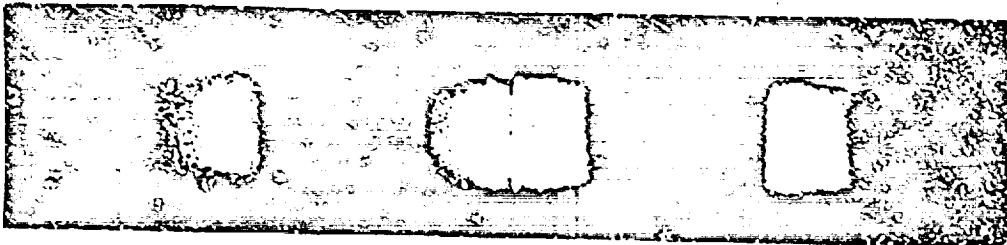
The  $\text{MgF}_2$  double Rochon prism appears to be a very useful vacuum ultraviolet polarizer, especially valuable in systems where simplicity of operation and calibration is an important factor. Comparison of the sample transmissions with the prism transmission shows that there may be additional gains to be made, perhaps in the preparation of the interface surfaces.

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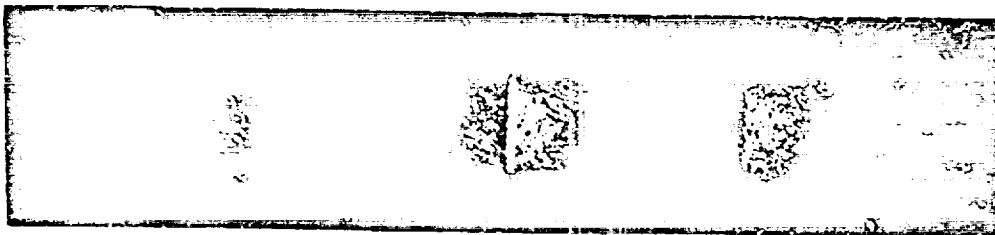
4. Thomas Teska, Lunar & Planetary Lab., to be published.



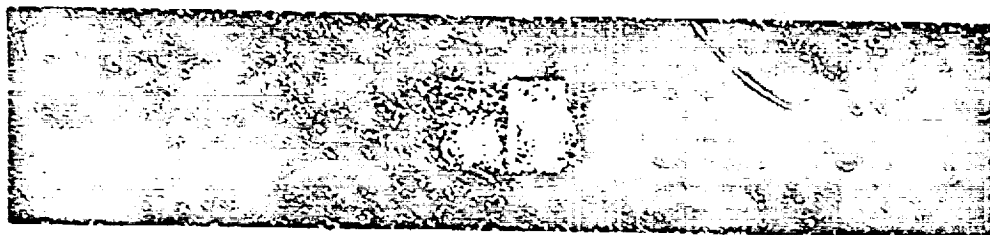
1360 A



1308 A



1294 A



1200 A

TABLE 2

THE INDICIES OF REFRACTION OF  $\text{MgF}_2$

$\lambda(\text{\AA})$	$n_e$	$n_o$
2893.59	1.40730	1.39485
2536.5	1.41483	1.40208
1849.68	1.44797	1.43424
1780 $\pm$ 2	1.45365	1.43975

ANGULAR BEAM DEVIATION (DEGREES)

